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**Final Report
Demonstration and Expanded Assessment of the
Dual Use of STEP Technology**

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March 1995

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FOREWORD

This report was prepared by the Environmental Research Institute of Michigan (ERIM) under contract DLA 900-88-D-0392 from the Defense Technical Information Center. Under this contract ERIM provides technical support to the Department of Defense (DoD) through its Infra-Red Information and Analysis (IRIA) Center.

The report documents the results of a series of technology demonstrations conducted by ERIM's Space Technology Education Program (STEP) between 1 August and 31 October, 1994. The STEP demonstrations used low-cost COTS technology for users of weather satellite data. These demonstrations were conducted on twelve different occasions for representatives of U.S. Government and non-profit organizations concerned with new technologies, education, and the environment.

This report also expands on previous work to describe the impediments to widespread dissemination and dual-use of STEP technology within the DoD and the education communities. It contrasts the use of direct satellite readout to capture weather satellite data with the availability of similar data from alternative sources such as the Internet.

Dr. Forrest Frank, former Program Manager, Information Analysis Centers, Defense Technical Information Center and Dr. Rodney C. Anderson, Director of IRIA, provided the technical direction for this program. In preparing this report, Thomas W. Wagner wishes to acknowledge the support and assistance of ERIM colleagues Peter Tchoryk and Mickey Trichel, however he alone is responsible for its contents.

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1.0 DEMONSTRATION AND IMPEDIMENTS

The Department of Defense has placed renewed emphasis on the transfer of DoD technology to the non-DoD and private sectors. The public concerns addressed by this new emphasis on DoD scientific and technical efforts goes to the strong commitment of the Administration to leverage DoD resources to enhance the global competitiveness of the U.S. economy. The Department of Defense has also recognized the increasing need to make the best use of available commercial off-the-shelf (COTS) technologies where doing so can permit DoD to meet operational requirements at lower cost and more rapidly develop, test, and evaluate unique DoD solutions. Considered in this report is the application of low-cost commercial technology assembled and tested by ERIM's Space Technology Education Program (STEP) in support of this DoD mission.

The objectives of this report are (1) to document the results of a series of demonstrations of STEP technology to representatives of U.S. Government agencies and non-government organizations (NGOs), and (2) to expand on considerations of the impediments to the use of STEP technology with respect to DoD's above stated mission. As part of this task we have reviewed current capabilities for obtaining weather satellite data from the Internet and its implications for the use of direct readout in the classroom. We have also provided a discussion of the role of satellite direct readout in relation to K-12 education.

1.1 INTRODUCTION TO DIRECT READOUT

"Direct readout" is herein defined as the capturing of image data directly from satellites and the processing of these data into information by the user. With direct readout there are no intermediate transmission or data interpretation steps between the satellite and the user. The user accesses primary scientific data. The most practical source of direct readout data are from the constellation of a dozen polar-orbiting and geostationary weather (environmental) satellites that continuously broadcast images to stations on the ground. These satellites are maintained by U.S., Russian, European, Japanese, and Chinese space and meteorological agencies.

The current availability of direct readout data is the result of two technological developments. One development is the direct and continuous broadcast of analog signals containing image information from satellites to simple antennas and radio receivers on the ground. Originally developed by NASA in the 1960s, most of the world's civilian weather satellites use this

direct broadcast capability. On the polar orbiting satellites this capability is referred to as APT (Automatic Picture Transmission); on the geostationary satellites, it is known as WEFAX (Weather Facsimile).

The other technology development that has facilitated applications of satellite direct readout is the advent of low-cost personal computers (PCs). These computers may be used with the simple antennas and receivers to capture and process the APT and WEFAX images into useful products. Over the past two decades, a handful of amateur radio operators, tinkering with radio and computer equipment, have developed capable software programs for receiving and deciphering the weather satellite signals. Today, low cost commercial versions of these systems are readily available from a dozen or more vendors -- mostly small businesses in the United States and Europe. Several thousand schools and colleges, and many more individuals around the world now have working direct readout stations and routinely receive these low resolution images. Appendix A provides a partial list of U.S. vendors of low cost direct readout equipment.

1.2 THE STEP STATION DEMONSTRATIONS

In July 1994, a portable STEP Direct Readout station was set-up in ERIM's Washington DC office in Arlington, VA. As described in a previous report¹, this STEP Direct Readout station incorporates the following:

1. commercial off-the-shelf (COTS) computer and antenna components;
2. portable technology for ease of assembly and off-site uses;
3. complete range of satellite image processing, enhancement, and printing functions;
4. modem and Ethernet data exchange, and networking capabilities;
5. manuals, tutorials, and example images in both hardware and software;

The components of this station are listed in Table 1.

¹ Wagner, Thomas W., February 1994. "Satellite Direct Readout: Opportunities for Science Education", ERIM-IRIA Report No. 253860-1-X(R). 21p plus appendix.

Table 1. COTS Components to the STEP Portable Station²

NEC UltraLite Versa 486/33C w 250 Mb removable hard drive
Active-matrix VGA, 256 color, 640X480 built-in display
8 Mb Memory card (for total 12 Mb RAM)
NiMH battery pack
NEC 20" SVGA color monitor
Docking Station and Receiver
SCSI Adapter (PCMCIA)
PC137 Quorum Receiver card
GTI Weatherfax scan card
Replicated notebook computer ports
Microphone and headphone port
PCMCIA 14.4 Kbps MODEM card and PCMCIA Ethernet card
2 Loop Yagi Antennas (for WEFAX reception) w 1691 MHz to 137 MHz downconverter
Turnstile APT antenna

This station and its selection of supporting pedagogical materials were available from August through November 1994 for a series of on-site demonstrations at the ERIM Washington, D.C. office. In addition, the satellite image processing and display portions of the station were used for off-site demonstrations at the facilities of several organizations. An ERIM staff member and recent graduate of Washington DC's Dunbar High School helped to set-up and maintain the station and to conduct the demonstrations. Twelve demonstrations involving 21 different people were conducted during this period and are summarized in Section 2 of this report.

² Designation of product brand names do not constitute an endorsement of these products by ERIM or by the Government of the United States.

1.3 IMPEDIMENTS IN K-12 EDUCATION

Real-time weather satellite data are useful for a variety of applications. However, these data are not widely used. The reasons relate to impediments in delivering of the data and uncertainties on the part of potential users concerning how these data contribute to their functional goals and objectives.

For example, impediments to the capture and use of low resolution APT and WEFAX data in K-12 classrooms were described in a previous report in this series³ and are summarized in Table 2 below.

Table 2. Impediments to Direct Readout in Education

Technology Awareness	Few K-12 educators (or others) are aware of the opportunities to directly access weather data directly from the satellites.
Cost and Complexity	Individual teachers find daunting both the set-up costs and technology requirements of direct readout earth stations.
Computer Literacy	Few K-12 teachers are comfortable enough with PC technology to introduce complex applications into their classrooms.
Curriculum Materials	Few tested lesson plans and curriculum materials are available that incorporate live satellite images.
Timeliness and Appropriateness	Appropriate images may not be available at a time needed to support particular lesson plans or content requirements. Student-initiated learning activities may not be compatible with traditional pedagogy.

These impediments are largely institutional and pedagogical in nature. From the STEP demonstrations it is seen that there are no inherent technical problems preventing use of direct readout in K-12 classrooms. However, overcoming the institutional and pedagogical impediments may involve changes in the educational environment that are challenging for classroom teachers to implement. These changes are complementary to ongoing Federal efforts to promote systemic change and national science and technology standards in our nation's schools. Uses of satellite

³ Wagner, *ibid.*

direct readout may give students more direct involvement in carrying out science- and technology-based activities than current textbook and workbook activities. Direct readout often involves self-directed, collaborative, and project-oriented activities.

1.4 IMAGES ON THE INTERNET

Weather satellite images are available from other sources via telecommunications, including the Internet. Images from these sources may be used for a variety of applications related to DoD and educational requirements. However, satellite data obtained from commercial or public sources are technically different from direct readout data in that only selected data are available and these are often preprocessed, compressed, and otherwise modified. Imagery available over the Internet or from other sources may or may not be useful for certain applications. The nature and sources of weather satellite data on the Internet are described in Section 3.

1.5 RESOLUTION ISSUES

Low spatial resolution is sometimes cited as a reason for the limited use of weather satellite images. There are two different resolutions: HRPT and APT/WEFAX. The capture and processing of each involves different levels of technical sophistication, with the latter being more appropriate for schools or remote installations.

Automatic Picture Transmission (ATP) and Weather Facsimile (WEFAX) data have spatial resolutions on the order of 4 to 16 kilometers. In addition to this low spatial resolution, only one or two spectral bands are transmitted as analog signals to the receiver at a single time. As a result, relatively modest, PC-based computer equipment may be used to capture and process these data. A 10 Mhz PC can keep up with the data transmission rates and the resulting raw data files are seldom larger than a couple of megabytes.

High Resolution Picture Transmission (HRPT) data are often used by university and professional organizations. These data may be captured in real time by fairly sophisticated stations or they may be obtained from NOAA or commercial providers. The commercial providers use dedicated transmission lines to supply the high resolution images to their customers. The reception of NOAA's AVHRR 1.1 kilometer resolution data may result in 100 megabytes of data in 15 minutes. A single GOES Variable Advanced Radiometer (GVAR) image covering the entire Western Hemisphere may create a 300 megabyte file size—every hour. Both the complexity of tracking these satellites and the computer requirements associated with receiving and storing large data files make these systems difficult to deploy in the use.

1.6 CLASSROOM PEDAGOGY

Low resolution satellite data may provide new opportunities for science learning and environmental analysis. The data support content requirements in earth, physical, and life science models and the use of advanced image processing and communication skills. Direct readout is an activity relevant to a wide variety of applications. In this role, satellite images may engage young minds and help educators to convey scientific concepts and mathematical and technical skills that learners will draw on throughout their lives. These aspects of direct readout is further described in Sections 4 and 5 of this report.

2.0 STEP DEMONSTRATIONS

STEP direct readout technology was demonstrated to representatives of the organizations listed in Table 3. Here is a summary of those presentations and the responses to the demonstrations.

Table 3. Organizations Receiving Demonstrations

<u>Organization</u>	<u>Agency</u>	<u>Date</u>
ARPA, U.S. Dept. of Defense	Computer Aided Education and Training Initiative (CAETI)	August
U.S. Dept. of Agriculture	Soil Conservation Service	September
U.S. Agency for Internat'l Development	General Programs	
National Aeronautics & Space Administration	Education Division, NASA HQ, Langley	September
Office of Science & Technology Policy	GLOBE Project	August
US Global Change Program	Earthlink Project	August
The World Bank	Asia Division, GIS Center	September & October
Academy for Educational Development	Educational Technologies	September
The Nature Conservancy		September
The Freedom Forum	Newseum Project	September

Advanced Research Projects Agency, U.S. Department of Defense

On 19th August, the STEP station and associated materials were demonstrated to Dr. Kristie Bellman, ARPA's Director for the Computer Aided-Education and Training Initiative (CAETI) and Mr. Paul Chatelier. Dr. Bellman used the station to display satellite images and commented on the educational applications of this technology. She appeared impressed with the range of supporting hardcopy and softcopy materials available. There seem to be an interest in incorporating this technology in CAETI's program to provide innovative technology support to the overseas Department of Defense Dependent Schools (DODDS) and other Federal K-12 schools.

U.S. Agency for International Development (USAID)

Dr. Anthony Meyer of USAID received a demonstration of the STEP station on September 7th. USAID is interested in this technology with respect to its applications to foreign assistance programs, especially those related to food security. The direct readout station was used to demonstrate applications to disaster early warning -- floods and cyclones (hurricanes) that frequently hit Bangladesh and the resulting damage to food crops. Currently high-resolution weather satellite data are used as part of the Africa Bureau's Famine Early Warning System (FEWS)⁴, but the STEP technology is suitable for transfer to participating countries of sub-Saharan Africa. The STEP technology may be successfully implemented in locations with limited power and technical support capabilities. This demonstration resulted in a continuing dialog with the Associates in Rural Development (ARD), USAID's recently selected prime contractor for Phase 3 of FEWS. It is anticipated that USAID's Office of Foreign Disaster Assistance (OFDA) will also contribute to this discussion.

U.S. Department of Agriculture Soil Conservation Service (SCS)

A STEP demonstration was conducted for Dr. Hari Eswan, USDA coordinator for IBSNAT (International Benchmark Sites Network for Agrotechnology Transfer) and Chief of the

⁴ Eilerts, Gary S, April 1993. "Information Presentation and Targeting for Early Warning and Global Food Security," Proceedings of the 25th International Remote Sensing and Global Environmental Change Conference, Graz, Austria. p. I-24-34.

newly developed SCS GIS mapping unit. Also participating was Dr. Richard Arnold, former Director of the SCS, and Lawson D. Spivey, Jr., soil scientist. Dr. Eswarn was interested in how direct readout might be used to provide current watershed and crop condition information. For example, the 10-year IBSNAT project has developed a number of sophisticated PC-based crop growth simulation models that make use of weather and soils data for predicting crop production at different locations. Currently models and decision support software are available for wheat, maize, soybean, peanut, rice, sorghum, millet, barley, dry bean, potato, cassava, and aroids.⁵ Dr. Eswarn is aware that current crop growth models may be calibrated and updated using these real-time satellite data. He provided several USDA points of contact for further discussions concerning the uses of this technology.

National Aeronautics & Space Administration Education Division

Dr. Ahmad Nuraddeen of NASA's Education Division twice visited the STEP demonstration facility -- the second time bringing Ms. Patricia A. Link, an education officer from the NASA

Langley Research Center in Hampton, Va. Dr. Nuraddeen was previously aware of STEP but is not associated with its development. On this occasion he requested ERIM to install a direct readout station in one of the local middle schools (Johnson Middle School) and to support its teachers in using this technology. (STEP is currently supporting teachers at Dunbar High School and Ballou High School in making use of this technology in Washington, DC.)⁶ He also requested additional copies of the STEP Teacher's Guide for distribution to colleagues and is considering supporting a satellite-linked teleconference for educators interested in this technology.

Office of Science & Technology Policy (OSTP)

Four key members (Drs. Barratt Rock, Tammy Blackwell, John Schmidt, and Deborah Gallaway) of the Office of Science Technology Policy's GLOBE Program received a demonstration of the STEP technology on August 24th. While they were intrigued by the STEP

⁵ International Benchmark Sites Network for Agrotechnology Transfer. 1993. "The IBSNAT decade." Dept. of Agronomy and Soil Science, University of Hawaii, Honolulu, Hi. 178p.

⁶ In a recent article in The Wall Street Journal (May 26, 1994), Ballou teacher Clarence Taylor was cited for his ability to interest under-achieving kids in academic subjects with weather satellite data.

technology, they were also interested in whether schools currently making use of direct readout might be brought into the GLOBE program. These representatives were quick to point out that GLOBE needs to create its own identity and database of projects and linkages. Ms. Blackwell commented favorably on the STEP interactive curriculum support program "Direct Readout Basics" and suggested that something like it could be developed for GLOBE.

US Global Change Program's (USGCRP) Project Earthlink

The STEP direct readout station was demonstrated to Dr. Lynn L. Mortensen of the U.S. Global Change Research Program, Working Group on Education and Communication (USDA, Rosslyn) on August 24th. As principle organizer of a recent K-12 educator conference on global change and the editor of its compendium of reference materials for teaching about global change and environmental education⁷, Dr. Mortensen was interested in the STEP Teacher's Guide and the ways in which direct readout contribute to the emerging National Standards for Science Education and GOALS-2000: Educate America Act. She requested and received a copy of the STEP Teacher's Guide and an updated version in October 1994.

The World Bank, Asia Division

Drs. Wayne Luscomb and Puneet Kisor of the Asia Division of the World Bank received demonstrations of the STEP technology in September and Mr. Glen Morgan of the same division was given a demonstration in October. Both demonstrations emphasized the COTS nature of the technology and the international aspects the weather monitoring and its importance for Third World agriculture. Dr. Kisor was particularly interested in developing GIS methods for integrating the satellite data with existing maps and statistics. He asked for and received a copy of the STEP Station Manual. Mr. Morgan commented that providing decision makers, both inside and outside of the Bank, with exposure to satellite direct readout may be a particularly effective way to educate them about the uses of modern remote sensing technologies. He saw the STEP technology as a catalyst for gaining high-level support for this and other types of remote sensing in the Bank's project portfolio. Subsequent to this demonstration, Mr. Morgan facilitated a meeting at the Bank to discuss applications of remote sensing to monitoring the rapid growth in Asian

⁷ Mortensen, Lynn L. (ed), 1994. Global Change Education Resource Guide, UCAR, NOAA Grant NA27GP0232. 1994.

cities. (Included in this subsequent meeting were P. Illangovan, Ramesh Ramankutty, and Lynn C. Holstein -- all of the Environment and Natural Resources Division.)

Academy for Educational Development (AED)

The Academy for Educational Development is a respected non-profit education and health research organization based in Washington , D.C. Since 1961, the Academy has conducted education and community development projects throughout the United States and in over 100 countries worldwide. Dr. Thomas D. Tilson, Vice President for Educational Technologies and Communication, was given a demonstration of STEP at the ERIM office and subsequently arranged for an off-site demonstration at the Academy. The Academy is interested in assessing the learning that comes from educational uses of direct readout. Specifically, the Academy has joined with ERIM in proposals to conduct assessments of STEP technology for the Department of Commerce Telecommunications Infrastructure Program and the ARPA's CAETI (see above).

The Nature Conservancy (TNC)

The Nature Conservancy makes use of COTS remote sensing technology in its environmental conservation efforts in the United States and in other countries, especially in Latin America. It is a partner with the U.S. Geological Survey and the National Parks Department in conducting detailed biodiversity surveys of the nation's National Parks. During this demonstration, TNC's Dr. Xiaojun Li commented that STEP technology could help support TNC's ongoing remote activities and tasks that effectively make use of direct readout.

The Freedom Forum (FF)

The Freedom Forum is a non-profit educational foundation supported by Gannett Press and dedicated to promoting and publicizing unrestricted access to information and news. In September, Messrs. Eric Newton and Thomas Bantel received demonstrations of the STEP station in ERIM's DC office. The Freedom Forum has offices in the same building and is in the process of building a museum dedicated to educating the public about the history of the free press -- the "Newseum". The museum will include facilities, including an auditorium for visiting school groups. Mr. Bantel was interested in incorporating the "real-time" aspects of direct readout as part of the Newseum's permanent display. However, he was interested in investigating the live

acquisition of high resolution imagery as part of this activity. The Newseum is expected to open in early 1997.

3.0 SATELLITE IMAGES ON THE INTERNET

Using modems, Gopher-client software, or World Wide Web (WWW) browsers, educators, are being taught to access and use current weather data to help teach earth and physical science and mathematics and technology in our nation's schools. Weather data are available from a number of Internet sources requiring different levels of computer and communications sophistication, ranging from PCs with 2400 baud modems to Unix workstations with high-capacity dedicated data lines. Some of the U.S. Internet sources and the types of supported connections are listed in Table 4 below.

Table 4. U.S. Internet Servers of Weather Satellite Images

<u>SAT/AREA</u>	<u>SERVER</u>	<u>CONNECT</u>	<u>IMAGES</u>
GOES-7, GOES-8, 4-2 km	National Aeronautics and Space Administration National Oceanic and Atmospheric Administration	ftp: explore.arc.nasa.gov /Pub/Weather	Doc, gif, grid, hdf, jpg, & mpg: Vis, IR2, IR3, IR4, IR5
GOES-7 (West) - North America	Univ. of Illinois Weather Machine (gopher) and Weather World (www)	Gopher wx.atmos.uiuc.edu/11/Images/ www.atmos/uiuc.edu/wxworld	B&W and color-enhanced gif images of East & West N.A. (640X480) and all N. America (1200X600), 12 image animation
GOES-8, radar-IR composite & Whole Earth	Univ. of Wisconsin SSEC	Gopher	Color-enhanced gif and 4 day mpeg animation
GOES-7, GMS	Michigan State Univ. Weather Browser	www: rs560.cl,msu.edu /weather/	Gif, jpeg, and mpeg
GOES-7, Indiana & N.A	Purdue University University of Michigan Weather Underground	Gopher: thunder//	Gif

Table 4. U.S. Internet Servers of Weather Satellite Images (continued)

DMSP	U.S. Defense Meteorological Satellite Program	Gopher: ndgc.noaa. gov/11/NGDC/	Archival: example vis and IR images
GOES-7 (Fla & Eastern US)	Florida State University	www: thunder.met.fsu. edu /explores/imagery	1 week archive GOES

3.1 UNIVERSITY SERVICES

Over the past six years the National Science Foundation has provided substantial funding for schools and universities to establish and upgrade facilities for receiving current weather data. From Table 3, it may be noted that universities are in the principle sources of weather data and images on the Internet. Most of these US universities are supported directly or indirectly by the National Science Foundation's Unidata Project.

Unidata

"Unidata" is an ongoing NSF program to promote university education and research in the atmospheric sciences. The Unidata Program Center is managed by the University Corporation for Atmospheric Research (UCAR) in Boulder, Colorado. The Center allows member university departments to access operational and research data products from NOAA NESDIS and the National Weather Service and other sources—including weather satellite images.

While the Center offers its member universities (estimated to be 130 at this time) a variety of free software and services, university departments are required to invest in the computers, network connections, personnel and other resources required for participation—although NSF may subsidize some of these costs as well. In addition, Unidata has joint software development arrangements with several commercial organizations.

Universities

Universities that receive Unidata services may make them more broadly available to their local educational community and, in the case of the University of Illinois (UoI) , Purdue University,

and the University of Michigan (UoM), to the Internet community at large. The most widely accessed Internet sources of satellite images are the University of Michigan "Weather Underground" and the University of Illinois "Weather Machine".

The Weather Machine

- The UoI Weather Machine receives 30,000 requests for data and information each day⁸ and makes the following images available over the Internet:
- GOES visible, daytime hourly, 8km resolution, 1200x600
- GOES infrared hourly, 8km resolution, 1200x600
- GOES water vapor, every 3 hours, 16km resolution, 640x350

From time to time, recent High Resolution Picture Transmission (HRPT) images of eastern North America, collected by the University of Toronto, were available on the Weather Machine as well. Use of this server has become so popular that at peak times it's difficult to access the network administrators have posted restrictions against automatic downloading of images. To help reduce the demand on this one server, other servers, referred to as "mirror sites" have set up.

Mirror Sites

FTP users can access weather-related software and archived (GIF-format) weather pictures by connecting to one of the mirror sites listed below:

Internet Address

early-bird.think.comm (131.239.2.1)

ftp.uwp.edu (131.210.1.4)

kestrel.umd.edu (129.2.110.31)

wmaps.aoc.nrao.edu (146.88.1.103)

wuarchive.wustl.edu (128.252.135.4)

wx.research.att.com (192.20.225.3)

⁸ Ramamurthy, M.K., and J.G. Kemp; October 1993. "Using the Weather Machine: A gopher server at the University of Illinois brings weather information to every desktop," Storm: The World Weather Magazine. p. 34-39.

Weather Underground and Blue Skies

Second to the UoI Weather Machine, the UoM Weather Machine makes over 100,000 electronic connections per week.⁹ Using a direct dial-up number, students can use this Gopher server to download a variety of National Weather Service and other public bulletins concerning world wide weather and geophysical events, such as earth quakes and floods.

Through a large NSF grant, the UoM developed of a popular graphical user interface for Macintosh computers called "Blue Skies". This interface and the tutorial materials created for it, allow students to acquire and display daily weather and other types of environmental data, including current ozone data of the Antarctic. While still requiring a classroom phone line and a high-speed modem, the interface is popular as an easy way to access current weather data over the Internet.

3.2 COMMERCIAL SERVICES

In association between Unidata, satellite images are supplied commercially by the Alden Weather Services. Alden is a for-profit company that sells and rents equipment for receiving satellite data over dedicated phone lines. Unidata helps influence the make-up of Alden's various data channels and subsidizes universities to make the cost of these data more affordable.

3.3 . INTERNATIONAL SERVICES

In addition to the U.S. Internet servers that provide access to satellite images, an number of non-U.S. servers are also available. Some of these are direct access sites; some simply share satellite images obtained from other sources. These are listed in Table 5.

⁹ Weather Underground, 1993. "Weather as a Paradigm for Instructional Technology", The University of Michigan, Ann Arbor.

Table 5. Non-U.S. Internet Sources for Weather Satellite Data

<u>SAT/AREA</u>	<u>SERVER</u>	<u>CONNECT</u>	<u>IMAGES</u>
GMS - Eastern Hemisphere	AARNet Archive	ftp-plaza.aarnet.edu.au/Weather/GMS	Anomation - mpeg hemisphere IR & Vis of last 24 hrs (1GB files)
NOAA - East Asia	Nationa Cancer Center (Toyko)	Gopher-gan.ncc.go.jp/00/INFO/weather	Color gif and jpeg (640X480) images of Japan and E. Asia
Meteosat & NOAA (Euro/Africa, & Atlantic Ocean)	Univ of Edinburgh	Gopher://gopher.ed.ac.uk/1	
Met-3	Univ. of Koln CSP, Italy Nottingham Univ.	ftp-cs.nott.ac.uk/11/.links.weather	B&W images of Europe and Africa
NOAA (Europe)	Univ. of Dundee		
NOAA & Met-5 (Europe)	Instit Meteor. FU - Berlin	www.met.fu-berlin.de/deutsch/Wetter	NOAA mosaics and Met5 48hr jpeg movies of Europe
NOAA 11 & 12	Univ. of Dundee Deutsches Klimarechenzentrum		
Meteosat (Americas)	INPE - Brazilian Space Agency		
NOAA (N.America)	University of Toronto	rainbow.physics.utoronto.ca	
NOAA (Asia)	Univ. of Toyko		
NOAA	ESA/ESRIN		

4.0 THE ROLE OF SATELLITE IMAGES IN LEARNING

Imaging is fundamental to human learning. Within several weeks of birth, an infant is using his eyes to obtain most of his environmental information—a process that continues throughout his life. It is estimated that 80 to 90% of the information that humans receive over a lifetime is in the form of images.

While traditional education directs major efforts at teaching literacy and numeracy, little organized effort is directed at teaching processes of image understanding—the art of reading, manipulating, and using images *per se*. This in spite of the fact that images provide a more fundamental pathway for learning than either literacy or numeracy and that members of different cultures learn to perceive visual space in different ways¹⁰. The absence of image understanding in curricula may have to do with historical limitations on the ability to manipulate and store images. However, modern image collection and processing techniques have change all that and our schools are just beginning to recognize that image understanding is an important part of the development process. There are many projects attempting to employ new multimedia and other imaging tools in creating compelling educational products.¹¹ Satellite images in the classroom provide an exciting means for teaching image processing and image understanding.

Satellite images extend the human visual system in ways unimaginable just a few years ago. They allow learners to observe the planet in near real-time at scales that range from their own local environment to the entire world. Satellite images involve students in using visualization tools for creating, storing, and transmitting images of the earth that convey different types of information. Using this technology, students capture new images and from these images, create accurate and interesting maps (analog simulations) of their environment—its major features, its land- or sea-scapes, and its changing patterns. Not only do students capture these images, but they manipulate them and enhance them in ways that both highlight and obscure different kinds of detail. Students learn to use images in creative ways to identify and extract different kinds of information—from animated movie “loops” of weather satellite images to composite map graphics.

¹⁰ Hall, Edward T., 1969. The Hidden Dimension, Doubleday Anchor, Garden City. 208p.

¹¹ One interesting project is the NSF-funded Learning through Collaborative Visualization (CoVis) Project being conducted by Northwestern University's Institute for the Learning Sciences.

4.1 LEARNING WITH IMAGES

On a cognitive level, the manipulation of images to convey information is a major pathway for learning. Classroom interactions with spatial data provide many different avenues for exploring of the physical environment and for extending of local knowledge in both time and space. Images provide students with information about local conditions without the time-consuming and sometimes risky necessity of direct physical contact. This exploration through images may go on at all grade levels and is not limited by language or mathematical abilities—images provide a universal language. Image data are particularly important in the sciences where continuous and accurate measurements provide the basis for scientific investigation and achievement. Modern satellite sensors continuously record the earth from above to document processes that are unobservable from the surface.

Students learn science by doing science. They learn to ask relevant scientific questions and work with authentic scientific data to help answer them. Daily weather satellite pictures provide students with graphic evidence of many counter-intuitive scientific concepts—the world is round; it is mainly covered by water; night and day, summer and winter co-exist on the planet; and what is felt as local weather is a manifestation of atmospheric processes that act with enormous amounts of energy over vast areas. These local conditions are the result of atmospheric processes taking place many miles away. From observing the earth with satellite images, students may learn to anticipate future events, to develop expectations based on current information. For example, by watching the movement of cloud patterns in relation to local weather, students discover a certain predictability to the weather. For example, in the temperate latitudes of the Northern Hemisphere he will observe that the weather patterns usually move from west to east, approaching clouds from the west may mean a forecast of precipitation.

With satellite images, students create intuitive models about the functioning of physical processes and from such models, they learn to make predictions about the future. Such predictions are important for learning. They involve students in anticipating the outcomes of planned or unplanned events and in assessing both the possibilities and risks of being wrong. Thus, in learning to work with images—all kinds of images—students have classroom models of real world scientific processes. Adding current data to these models, students answer questions that are of interest—in the process promoting inquiry, observation, examination of evidence, hypothesis testing, and confirmation of predictions and results.

4.2 IMAGES: GOOD AND BAD

In his book Mind and Nature,¹² Gregory Bateson points out that “image formation is perhaps a convenient or economical method of passing information across some sort of interface... Notably, where a person must act in a context between two machines, it is convenient to have the machines feed their information to him or her in image form.” He continues, “If that speculation is correct, then it would be reasonable to guess that mammals form images because the mental processes of mammals must deal with many interfaces.”

In communication there may be different kinds of images: good images, bad images, and raw images. Good images are defined as those that clearly and accurately portray information about the world. Good images are visual abstractions that accurately portray spatial aspects of reality. The term “band image” is a bit misleading. Bad images are images that present a confused or misleading picture of reality. Often such images are created for very legitimate reasons. Advertisements and movies often exaggerate or misrepresent reality for specific purposes. It is important for students to understand how images may be used to create a picture of a reality that doesn’t exist— staged or doctored images are often meant to deceive the viewer on a superficial level. Raw images are the original data from which good or bad images are made.

Image processing is routinely used to enhance or highlight a desired information content. The processing may be as simple as “contrast stretching”—changing the image gray scale or “tone” to better represent the range of analog values that encompass the image data. Or image processing may be as complex as image rectification and classification, wherein the image is resampled to improve its spatial accuracy and where all but those portions of the image that represent particular features of interest are eliminated from consideration. Clearly the development of such skills by students would have significance for the DoD mission.

4.3 SCIENCE AND COMPUTER LITERACY

Question: What’s the difference between “computer literacy” and “scientific literacy”.

Answer: You can be “computer-literate” but not “scientifically-literate”, but you cannot be “scientifically-literate” without being “computer-literate”.

Today, learning science goes hand-in-hand with learning to use computers. The reason is simple. Science is the process of collecting, processing, analyzing, and publicizing data—all kinds

¹² Bateson, Gregory, 1979. Mind and Nature: A Necessary Unity, Bantam Books, New York. p38.

of data, usually new data but often old data as well, data that leads to new scientific discoveries and new information -- and that's what computers do.

In most areas of science, computers either provide or mediate the means of data collection. They receive, store, and calibrate data. They allow a variety of simple and sophisticated ways for analyzing and displaying the data—the heart of the scientific process. Finally, computers allow the results of this analysis, the new information, to be transcribed and communicated to others.

The difference between a technician or engineer and a scientist is in knowing how each of these computer-mediated activities are organized to produce an answer to a scientific question. Knowing the scientific question and knowing how to arrive at an answer is prerequisite to being a scientist. Using this knowledge is the scientist's job. Inevitably, this means knowing the applications of computers and other electronic systems. While perhaps not to the same depth as the computer technician or engineer, the scientist must have a working knowledge of how the data relevant to his or her field are collected, how they are processed, and how they are analyzed. In addition, he must be able to effectively share data and information, and communicate results.

4.4 LEVELS OF COMPUTER LITERACY

Computer literacy may be associated with three levels of the scientific process: (1) the technical, (2) the applications, and (3) the networking. Today's scientist must be competent in all three. While he tends to focus on the applications, he must be able to use the others and each of these levels must be part of his education.

At the technical level the scientist must understand how modern electronic devices, including computers, are used to collect and process scientific data. While once simple (analog) instruments gave simple readings of scientific measurements that were, in-turn, read and recorded by hand, today sophisticated electronic instruments and sensors provide highly mediated readings of many different measurements. The measurements are detailed, specific, and voluminous. Often the data recording process goes through several steps, transforming the data each time before the data reaches the scientist. Each data record and each transformation brings opportunities for data enhancement and for data corruption. The scientist must understand those steps and what good data looks like or he runs the risk of missing valuable data or of being fooled by his data. If he doesn't understand the primary data with which he works—how they were collected and processed prior to reaching him—his efforts may be lost from the start.

Also at the technical level, the scientist must understand the ways in which computers receive, store, retrieve, and how display data. At the applications level, computers provide the ability to process data in many different ways. Each scientific field has processing procedures and applications that are accepted as appropriate for that field. Those acceptable for one may not be acceptable or understood by another—partly because they may not give the right answer but also because the scientists in that field may not understand the answers for that process. For example, there are many statistical measures used in analyzing numerical data, but each measure involves certain conditions or assumptions concerning the data to be processed. Without understanding the underlying assumptions (perhaps concerning the representativeness or the distribution of the data), the results may not be correctly interpreted. Without understanding where the data came from and how it was collected (at least generally), it is risky to apply specific analysis tools, but unfortunately it is a common occurrence for non-scientists to do so and purport to have achieved new scientific results. Scientists must know which process(es) to use in analyzing their data; and in what order to use several procedures and how to interpret the results.

At the computer network level, scientists must know both how to obtain and how to share data and results with others. Increasingly, scientific achievements come, not from a single scientist working alone in his lab, but from collaboration of a number of scientists and others working together. Usually that means sharing or exchanging data and information back and forth from different locations in the same building, different buildings in the same town, and across the country and the world. Thus, today's scientist must be skilled at computer networking and at telecommunications; he must not only be able to generate new information but be able to identify important data and information sources and to share his data and information across networks of computers.

5.0 SATELLITE IMAGES IN THE CLASSROOM

Why should a K-12 classroom teacher be interested in weather satellite images. The reason is that these images and the process of obtaining them stimulate student learning and provide a compelling model for building scientifically sound concepts related physical earth processes. Satellite images can enhance and complement lessons in mathematics, physical and earth sciences, computers and other information technologies. These activities, in turn, can contribute to a host of related subjects. Capturing up-to-the-minute earth pictures of your location and of other parts of the world makes science and technology come alive and involves kids in locally relevant activities. It builds on their concerns for the environment and on their enthusiasm for space technology.

5.1 MULTIDIMENSIONAL ACTIVITIES

The classroom activities may be multidimensional as well as multidisciplinary. They encompass different learning styles --visual, auditory, and kinesthetic. They provide opportunities for individual or group learning, and the sharing of information across classrooms and districts to other states and to foreign countries. The activities are immediate and relevant—allowing students to work with authentic scientific data, to “do science.”¹³ In summary, the use of satellite images provides a classroom model of the scientific process and to learn scientific methods.¹⁴ It stimulates a multidisciplinary and hands-on approach to learning, and links the student’s own class room to the local environment, and the local environment to the world-at-large.

Satellite images observe and record large areas in short intervals of time so that physical events, such as the prevailing weather, vegetation changes, or ocean processes may be identified and monitored. Computers are used to display these data and transform them into useful information. It provides incentive for information sharing and promotes problem-solving activities.

¹³ For example see Fishman, Barry J. and Laura M. D’Amico, 1994. “Which Way will the wind blow,” 1994 Education Hypermedia and Multimedia Annual.

¹⁴ This model is described in detail in Wagner’s STEP Teacher’s Guide. See Bibliography.

On another level, access to daily weather images is a demonstration to students of the right of individuals in a free society to access public scientific data and information.

5.2 NEW EDUCATION STANDARDS

The American Association for the Advancement of Science (AAAS), the National Council of Teachers of Mathematics, the National Science Foundation (NSF), the U.S. Department of Education and many other organizations concerned with education in this country are promoting guidelines and goals for teaching K-12 students today that are keeping with the types of activities that satellite images may be used for. For example, the AAAS Project 2061: "Science for all Americans" states the following :

Scientifically literate citizens

- Are familiar with the natural world, its diversity and its unity
- Understand key scientific concepts and principles
- Know that science, mathematics, and technology depend upon one another
- Know that science, math, and technology are incomplete human bodies of knowledge
- Are able to reason scientifically;
- Can use scientific knowledge and ways of thinking for individual and social purposes and problem-solving.

The way these guidelines are stated may vary, but there is converging agreement on what they mean for classroom curricula and practice. For example, in putting these AAAS guidelines into practice, the following principles have been recommended:

- Promote integration in the three basic scientific fields of study: life science, physical science, and earth and space science.
- Present science in connection with its applications in technology and its implications for society;
- Present science in connection with students' own experiences and interests, frequently using hands-on experiences that are integral to the instructional process;
- Provide students with opportunities to construct the important ideas of science and reflect on historical and cultural perspectives that are then developed in depth and through inquiry and investigation; and

- Provide students with fewer content topics but teach these in greater depth, as well as teach them to reason logically and evaluate critically the results and conclusions of scientific investigations.

These AAAS guidelines emphasize understanding over content; learning that is useful outside the school; scientific literacy for all students; and interdisciplinary learning. While many educators agree in principle with these goals and guidelines, there is little in the way of materials available today to help teachers implement them.

Satellite images derive their unique educational qualities from their ability to involve young people directly in the scientific observation of the planet. They help link classrooms to the constellation of multinational satellites used for observing weather events—events that demonstrably affect human lives. Involving students in applying these data results in a high level of interest and learning. Similar information in textbooks, over electronic computer networks, or even by television simply is not the same. Prepackaged information or activities do not invoke the same level of interest or creativity in students.

Satellite images provide a basis for instructional content on many levels, making them appropriate for classrooms ranging from kindergarten through senior high school. At the primary level, children entering the primary grades often bring with them firm but incorrect ideas about the spatial nature of their world and their position within it. They see their own environment as represented by a flat earth, and its events, such as its current weather, time of day, or season of the year as going on all over the world. However, the daily self-reinforcing evidence of earth images help to dispel these local, flat-earth models and provide young children with a valid global frame of reference upon which to build concepts as time, seasonal change, direction and distance, spatial scale, place and location, weather and climate processes, and energy and communications. Their ability to visually integrate basic concepts in science, mathematics, information technologies, and social science makes them suitable for most middle and senior high school science curricula as well. Their applications may well extend to university levels. For example, here are some different science concepts that may be illustrated and given concrete meaning with these images.

Table 6. Example Educational Concepts

<u>Domain</u>	<u>Concepts</u>
Physical Science	Energy (EMR, radiation, temperature, gravity), matter (composition, reflectance, structure)
Earth & Space Science	Geo-chemical cycles, landforms and weathering, ocean and atmospheric circulation, geographical location, mapping
Life Sciences	Biomes, climatic zones, annual and perennial changes
Mathematics	Measurement, change, rate-of-change, orbital geometry
Social Science	Economics, decision-making, human values.
Technology	Computers, electronics, sensors, communication, displays
Information Science	Data representation, storage; information, knowledge

The satellite images show in great detail, not only the locations of clouds and continents, but the temperatures of ocean currents, the patterns of land use, and the movement of hurricanes and storm systems across the hemispheres. Because of their timeliness and comprehensives, these images provide a wealth of geographic information and are widely perceived as important data for teaching the physical and earth sciences, mathematics, and technology in our nation's schools. At apparently minimal cost, individual teachers and schools systems are encouraged to make provisions for accessing these data in their classrooms.

6.0 CONCLUSIONS

From the foregoing, we have attempted to provide a pedagogical basis for expecting that satellite images, especially real-time satellite images, will contribute to science and technology learning in K-12 classrooms. However, to date satellite images have had little impact on the current education system or on the way science is taught in the classroom. The reasons for the limited impact are not only institutional and pedagogical, but disciplinary as well. The meteorological community, for which the satellites were created, may be reluctant to concede that these images may be a catalyst for learning without their direct involvement..

6.1 INFORMATION VERSUS LEARNING TECHNOLOGIES

Satellite images are a product of an information technology—a technology designed to deliver real-time images that relate information about the condition or status of the environment, primarily the atmosphere, but ocean and land areas as well. The technology was designed for use by the meteorological community and is managed by the meteorological community. Its products serve the meteorological community and were not conceived as directly serving K-12 education. The fact they are being used in education and that use is growing, is testimony to the robustness of the potential applications — almost inadvertently, weather satellite images have found their way into the classroom.

We believe the learning opportunities afforded by these data extend significantly beyond simply teaching about weather and climate at middle or high school levels. The classroom applications of live satellite data provide a broad stimulus to learning in a number of different subjects and in ways that speak to different student learning styles throughout the K-12 range.

However, there is a misconception that learning from the images available over the Internet and the data available through direct readout are interchangeable. This is not the case. In general direct readout provides a richer educational experience, but involves greater organization and preparation than the accessing of weather satellite images from the Internet. The student's ability to acquire and process low resolution APT and Wefax data directly from the satellites provides greater opportunities for student involvement with the data and a more complete classroom model of the "real world" scientific process.

- Direct readout requires a higher initial set-up effort than accessing data over the Internet, but has no recurring data or facility costs after the initial set-up. Relatively little attention and only modest support has been directed to making direct readout technologies available to K-12 schools. The reason for the reluctance of federal agencies to fund direct readout activities may be an idea that a direct readout station are too difficult for students and teachers to assemble and use.

6.2 A CASE FOR A STATE-OPERATED HRPT STATION

One suggestion is for local universities or state department of education to operate high resolution stations exclusively for their state. Such stations could routinely obtain, disseminate, and archive data for just its state or a portion of the state that is of local interest.

- Such a local HRPT satellite stations could:
- Provide assured real-time access to and archival of local HRPT/VAS data (including, non-US satellite data).
- Allow electronic (inc. Internet) transmission of full data sets to classrooms for processing and using with locally obtained ground truth.

Regional or state-wide satellite data can provide a basis for coordinated regional or state-wide school activities or competitions.

- Provides economical data access and future system growth
- Help develop applications of space technology for student education and teacher training.

Currently under several sources of funding, both West University and Alma College have operating HRPT stations that could be used to supply neighboring school systems with high resolution satellite images.

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APPENDIX A . VENDORS OF LOW-RESOLUTION DIRECT READOUT STATIONS

Amsat
PO Box 27
Washington, DC 20044
(301) 589-6062, Fax (301) 608-3410

Aquila Systems , Inc.
928 Old Colchester Rd.
Oakdale, CT 06370
(203) 848-1493
Contact: Steven Rocketto

Fischer Scientific Co.
485 S. Frontage Rd.
Burr Ridge, IL 60521
(800) 955-1126, Fax (312) 378-7174
Contact: Bruce Sanders

GTI Electronics
1541 Fritz Valley Rd.
Lehigh, PA 18235
(717) 386-4032. Fax 717-386-5063
Contact: George Islieb

Lone Eagle Systems, Inc.
5968 Wenningoff Road
Omaha, NE 68134
(402) 571-0102

OFS Weatherfax
6404 Lakerest Court
Raleigh, North Carolina 27612
(919) 847-4545

Quorum Communications, Inc.
8304 Esters Blvd. Ste 850
Irving, TX 75063
(214) 915-0256, Fax (214) 915 0270
Richard Fogle

Roffsat, Inc.
2871 SW 69th Court
Miami, FL 33155
(305) 262-8336
Contact: Mitch Roffer

Satellite Data Systems (SDS)
P.O. Box 219
Cleveland, MN 56017
(507) 931-4849
Contact: Loren Johnson

Software Systems Consulting
615 El Camino Real, San Clemente, CA
92672
(714) 498-5784, Fax (714) 498-0568
Contact: John E. Hoot

METSAT Products, Inc.
1257 Glenmeadow Lane
East Lansing, MI 48823
(517) 332-7665
Contact: Ralph Taggert

Spectrum International Inc.
P.O. Box 1084
Concord, MA 01742
(508) 263-2145, Fax (508) 263-7008
Contact: C.J. Beanland

Multifax
143 Rollin Irish Road
Milton, VT 05468
(802) 893-7008, Fax (802) 893-6859
Contact: Wm. Schwittek

Tri-Space, Inc.
P.O. Box 7166
McLean, VA 22106-7166
(703) 442-0666, Fax (703) 442-9677
Contact: Ann Berman

WeatherTrac Industries
860 Worcester Rd.
Framingham, MA 07010
(508) 879-4425, Fax (508) 879-8951
Contact: Mark Lowenstien

APPENDIX B: VENDORS OF HIGH-RESOLUTION DIRECT READOUT STATIONS

Dartcom
Ben Olivier
no phone number available

Dundee Satellite Systems
Peter Bayliss
44-382-231-81 (phone)
44-382-202-830 (fax)

Global Imaging
Steve Borders
619-481-5750 (phone)
619-481-5794 (fax)

GTI Electronics
George Isleib
717-386-4032 (phone)
717-386-5063 (fax)

IPS
Bo Bjarno
415-592-1742 (phone)
415-592-3544 (fax)

MacDonald Dettweiler
Mr. Richard Brown
604-278-3411 (phone)
604-278-0531 (fax)
no longer provides systems

Quorum
Alan Bundes
817-488-4861 (phone)
817-488-7861 (fax)

Satlantic Inc.
Marlon Lewis
902-492-4780 (phone)
902-492-4781 (fax)

SeaSpace
Buzz Bernstein/Hawley Sandfer
619-578-4010 (phone)
619-578-3625 (fax)

SmartTech
Kevin Davis
803-795-5621 (phone)
803-795-5793 (fax)

Systems West
Kenneth Tuggles
408-625-6911 (phone)
408-625-6914 (fax)

Telonics
David Beatty/Richard Holien
602-892-4444 (phone)
602-892-9139 (fax)